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MONITORING OF NATURAL BACKGROUND GAMMA RADIATION AT GROUND LEVEL IN SÃO JOSÉ DOS CAMPOS, SP, BRAZIL

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ABSTRACT

A pilot study has been conducted to determine the feasibility of using low-cost portable instrument to measure and characterize the background gamma radiation in São JosE dos Campos, SP, Brazil. A NaI(Tl) scintillator coupled to a photomultiplier and connected to a PC recorded variations of the local background gamma radiation over extended periods of time. The collected data show that there is a correlation between meteorological phenomena and the radiation level. This correlation can be attributed to variations in the concentration of radon gas at ground level produced by these meteorological phenomena. Measurements of energy calibration, stability and reproducibility of system were made during the work.

KEYWORDS: Gamma Radiation, Radon, NaI(Tl) Scintillator, Meteorological Phenomena

INTRODUCTION

The environment is exposed to different radiation sources, e.g., radioactive isotopes of uranium, thorium, potassium (in the soil), radon gas (in the air and water wells), cosmic rays and anthropogenic sources (industry, energy production, medicine) (Eisenbud and Gesell, 1997). All these sources contribute to the background gamma radiation. Natural factors such as meteorological (Hosler, 1966), astronomical (Grieder, 2001) geological (Alekseenko et al., 2010) and even biological (Pearson et al., 1966) phenomena can also interfere with the radiation background. In the region of São JosE dos Campos (SP, Brazil, 23°11′11″ S, 45° 52′ 43″ W; altitude, 660 m) measurements or data on the radiation background are either scarce or based on historical mean values. In the case of unforeseen natural events or human-caused accidents, the radiation count can change significantly in short time scales (hour or days) but depending on local conditions these unexpected changes can be masked by changes in the gamma radiation background caused by natural phenomena (Eisenbud and Gesell, 1997). Hence, with aim of understanding how the background gamma radiation varies over time and is affected by natural phenomena, we established a pilot program to record time series of gamma radiation (energy, 0.03 to 10 MeV) measured at ground level using low-cost portable instruments.

METHODS AND RESULTS

A NaI(Tl) scintillator crystal (dimensions, 7.5 x 7.5 cm) optically coupled to a photomultiplier tube (PMT), in a 2 mm thick aluminum cylinder was used to detect gamma radiation. The PMT is connected to a PC through an amplifier/digitizer interface (Aware Electronics, USA). Figure 1 shows the crystal/PMT housing and the amplifier/digitizer interface.

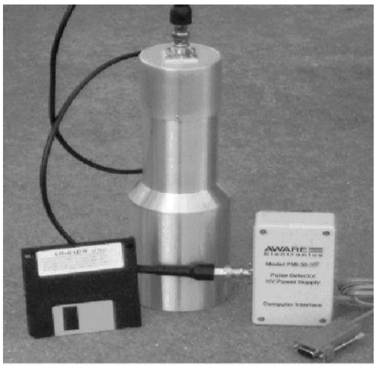

Figure 1: NaI (Tl) Scintillator / PMT in Aluminum Housing and Amplifier/Digitizer Interface Floppy Disk for Scale

Data were sampled and recorded at one-minute intervals. Data were collected uninterruptedly for periods as long as 90 days. The detector was located inside a room on the second floor of a two-floor building with brick walls and clay roof tiles. Figure 2 shows an example of the data recorded. Data are presented in raw format, as they were collected.

Three important features can be noted in Figure 1. The diurnal variation of the intensity of the background radiation caused by changes in the concentration of radon gas (^{222}Rn) in the atmosphere, which is primarily controlled by small scale eddy dynamics of the low atmospheric boundary and variations of the temperature and humidity of the atmosphere and soil during the day. (2) Significant and rapid increases in the radiation count caused by meteorological phenomena, especially rainfall. This rapid increase is produced by radon washout, which is a process whereby the radon present in the atmosphere is collected by rain and deposited on the ground. (3) Atmospheric conditions associated with foggy days favor an increase in the concentration of radon at ground level. Other authors have also reported similar findings using more complex instruments (Porstendörfer et al., 1991, Fujinami, 2009, Ichiji and Hattori, 2012).

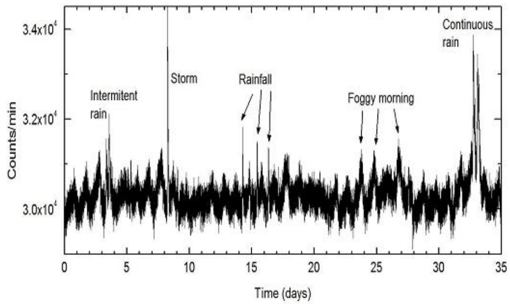

Figure 2: Background Gamma Radiation Measured at São Jose Dos Campos, SP, Brazil. Measurements Started March, 3, 2012. Meteorological Events were Observed Visually by the Authors

Figure 3 shows with more detail the event that occurred around day 8 (Storm) of Figure 1. The rapid increase of radiation counts during precipitation is followed by an exponential decay.

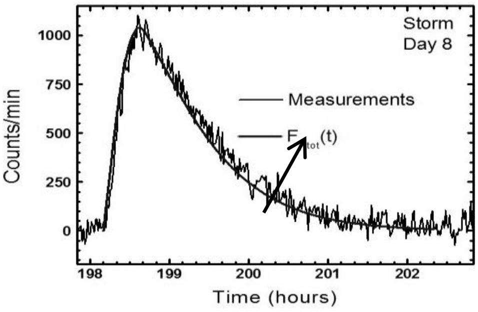

Figure 3: Time Profile of the Gamma Radiation Intensity during and after a Rainfall (Black Line) and a Least-Square Fit using an Exponential Function. Mean Value of the Number of Counts per Minute was Subtracted

The shape of the curves observed in Figure 3 is determined by a balance between intensity of the radiation arising from the radioactive decay of the radon washout. The progeny of radon is:

$$^{222}Rn \rightarrow {}^{218}Po \rightarrow {}^{214} \tag{1}$$

The decay process is described using a system of two differential equations (Magill and Galy, 2004):

$$\frac{\partial N_{214Pb}(t)}{\partial t} = I_{214Pb}(t) - N_{214Pb}(t)/t_{214Pb} \tag{2a}$$

$$\frac{\partial N_{214Bi}(t)}{\partial t} = I_{214Bi}(t) - N_{214Bi}(t)/t_{214Bi} \tag{2b}$$

Because of the short half-life of ^{214}Po decay (164.5 μs), its contribution to the total gamma intensity is equal to that from ^{214}Bi; Thus, the total flux of gamma radiation is:

$$F_{\gamma-tot} = N_{214Pb}(t)/t_{214Pb} + N_{214Bi}(\tag{3}$$

where t is time in seconds.

A least square fit using exponential decay functions shows that the exponential decay observed in Figure 3 has an approximate half-life time of 60 min, which is characteristic of the total decay of ^{222}Rn progenies.

CONCLUSIONS

This is a pilot study still in its development phase. We plan to add to our set of instruments, meteorological instruments to record the variation of atmospheric pressure, precipitation, wind speed and intensity, air temperature and humidity so that it will be possible to characterize more precisely how atmospheric phenomena can affect the gamma radiation background, and specially the concentration of radon gas at ground level over time. Still, the data we have collected demonstrate that it is possible to observe changes in the background radiation using compact instruments. Additionally, this type of study emphasizes the importance of continuous monitoring of background radiation in view of recent nuclear accidents; changes in the background radiation can be affected by meteorological phenomena and can disrupt the normal monitoring of radiation in nuclear facilities, hospitals and the industry.

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REFERENCES

1. Alekseenko, V. V., Gavriluk, Y. M., Kuzminov, V. V. & Stenkin, Y. V. (2010). Tidal effect in the radon-due neutron flux from the Earth's crust. Journal of Physics: Conference Series, 203, 1, 1-3

2. Fujinami, N. (2009). Study of radon progeny distribution and radiation dose rate in the atmosphere, Jpn. J. Health Phys., 44, 1, 88-94

3. Hosler, C. R. (1966). Meteorological effects on atmospheric concentration of radon (Rn^{222}), RaB (Pb^{214}), and RaC (Bi^{214}) near the ground, Monthly Weather Review, 94, 2, 89-99

4. Ichiji, T., & Hattori, T. (2012). Continuous measurement of environmental gamma radiation in Tokyo using Ge semiconductor detector, IRPA homepage, Retrieved from http://www.irpa.net/irpa10/cdrom/00611.pdf

5. Joseph Magill & Jean Galy. (2005). Radioactivity Radionuclides Radiation, New York: Springer

6. Merril Eisenbud & Thomas Gesell. (1997). Environmental Radioactivity from Natural, Industrial & Military Sources, 4th ed. London: Academic Press

7. Pearson, J. E., & Jones, G. E. (1966). Soil concentrations of “emanating radium-226” and the emanation of radon-222 from soils and plants, Tellus XVIII, 2, 656-662

8. Peter K. F. Grieder. (2001). Cosmic Rays at Earth, Amsterdam: Elsevier

9. Porstendörfer, J., Butterweck, G., & Reineking, A., (1991). Diurnal variation of the concentrations of radon and its short-lived daughters in the atmosphere near the ground, Atmospheric Environment. Part A., 4, 3-4, 709-713